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A Preliminary Report on the Relative Value of Various Phosphate Fertilizers for Southern Idaho Soil Conditions

By
H. W. E. LARSON AND G. ORIEN BAKER

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Summary

1. A comparison of the results obtained from various kinds of phosphate fertilizers in tests conducted by the Experiment Station and Extension Division of the University of Idaho and the Idaho Phosphate Commission are presented and briefly discussed.

2. Fertilizer tests were made on the following crops: Alfalfa hay, sugar beets, red clover, potatoes, wheat, barley, oats, peas, corn, beans, and onions.

3. Western treble and TVA triple superphosphate applications produced the most economical return per dollar invested in phosphate fertilizer when all crops were considered.

4. The least economical returns were obtained from the application of rock phosphate, either regular or finely ground.

5. TVA fused, TVA meta and Bureau calcined applications produced returns at intermediate cost.

A Preliminary Report on the Relative Value of Various Phosphate Fertilizers for Southern Idaho Soil Conditions

H. W. E. Larson and G. Orien Baker*

Introduction

THE use of commercial fertilizers in Idaho has increased from approximately 100 tons in 1918 to over 4000 tons in 1938. Western treble superphosphate has constituted by far the largest percentage of these sales. The use of readily available phosphate fertilizers should continue to increase, particularly in the irrigated sections of southern Idaho. Observations and tests indicate that the longer irrigated land is under cultivation the greater is the need for additions of readily available phosphate fertilizers in order to maintain good crop production.

The first work conducted by the University of Idaho on the use of phosphates as a fertilizer was at the Agricultural Experiment Station, Moscow, in 1915. Phosphate investigations were started at Sandpoint, Aberdeen, High Altitude, and Caldwell branch experiment stations in 1918, 1921, 1934, and 1935, respectively. Farm demonstrations in cooperation with farmers were started by the Agricultural Extension Division in 1930. Tests with various phosphate fertilizers have been continued and the program enlarged throughout the State during the intervening years.

During the first years the experiments and demonstrations (tests) dealt mostly with the value of readily available phosphate fertilizers on various soils and for different crops. The testing program was then enlarged to determine the effect of various kinds of phosphate fertilizers on crop yields. Tests, conducted in 1931 and 1932 on farms in the upper Snake river valley, (*10*) included the application of rock phosphate and western treble superphosphate. Similar tests were started at the Aberdeen Branch Experiment Station in 1935. During the past few years various new kinds of phosphate fertilizers have been manufactured. In order to obtain information as to their efficiency as sources of phosphorus for plants under Idaho conditions, more comprehensive tests were conducted by the Experiment Station and Extension Division during 1937 and 1938. The Idaho Phosphate Commission in cooperation with the State Grange and Extension Division, supervised a series of tests in 1938.

The Tennessee Valley Authority furnished a small quantity of meta phosphate and fused phosphate for use in 1937. In 1938 TVA contributed a 30 ton carload consisting of 27 tons of triple superphosphate, 2 tons of meta phosphate, and 1 ton of fused phosphate for testing purposes. The Idaho Phosphate Commission cooperated by paying the freight on this carload shipment. The Bureau of Chemistry and Soils, U. S. Department of Agriculture, cooperated in 1937 by donating a small shipment of cal-

*Soils Specialist and Soil Technologist, respectively.

cined phosphate. The western treble superphosphate used in these tests was donated by the Anaconda Sales Company, Fertilizer Department.

The soils in the various areas of Idaho vary widely in their available phosphate content. Some of the factors which may influence the response of the crop to phosphate fertilization are amount of lime present in the soil, lack of uniformity of soil, soil type, insects and diseases, amount of readily decomposible organic matter present, seasonal conditions, rotation, irrigation methods, and previous management practices. Southwestern Idaho soils have not responded to readily available phosphate fertilizer applications as uniformly in the past as have those in the middle Snake and upper Snake river areas. However, the response has become more marked in the first mentioned area each succeeding year.

Deficiency of readily available phosphate in soils may be indicated by means of field tests, laboratory analyses and by noting the plant deficiency symptoms. Proper soil analysis gives an indication of the amount of readily available phosphate present and may be used as a basis for phosphate recommendations, when due consideration is given to the kind of crop, soil conditions, and management practices (*8*). Due to the wide variations in soil conditions, tests should be conducted by the individual farmer on his own land to determine the profitableness of phosphate applications under his conditions.

Methods of Manufacturing Different Kinds of Posphate Fertilizers

A brief statement regarding the method of preparation of each product is given to assist the reader in understanding the terminology and results presented in this publication.

Rock phosphate, regular, is prepared by grinding "mine run" rock phosphate so that all of it will pass through a 60 mesh screen. Frequently 50 to 60 per cent of this material will pass through a 200 mesh screen.

Rock phosphate, fine, is prepared by grinding the "mine run" rock phosphate so that all of it will pass through a 200 mesh screen. A large proportion of the material is much finer than 200 mesh.

Western treble superphosphate, used in these tests, is prepared by treating ground rock phosphate with dilute sulfuric acid in proper proportions. Gypsum and phosphoric acid are the products of this reaction. The phosphoric acid is then separated, concentrated by evaporation, and mixed with more ground rock phosphate. The mixture is permitted to cure and is then reground to desired fineness.

TVA triple superphosphate (*2*). The phosphoric acid (*1*) required for preparing this product is made by first smelting rock phosphate with coke and silica in an electric furnace. The evolved gases are burned and the phosphorus pentoxide fumes are passed into water, thereby producing phosphoric acid. This acid is mixed with powdered rock phosphate in proper proportions. The mixture is permitted to cure and is then reground to desired fineness.

TVA meta phosphate (*3*) is prepared by passing gaseous phosphorus pentoxide prepared as for TVA triple superphosphate into a stream of dry air which then passes upward through a vertical column of finely

ground rock prosphate which has been heated from 2012 to 2224 degrees Fahrenheit. A liquid is produced which upon cooling becomes a semi-transparent, glassy material. It is reground before marketing.

Fused phosphate (*4*) is prepared by passing dry steam for a period of 5 to 15 minutes through a molten mass of rock phosphate, which has been heated to at least 2732 degrees Fahrenheit.

Bureau calcined phosphate (*9*) is prepared by heating 40 to 80 mesh rock phosphate in the presence of water vapor for 30 minutes at approximately 2552 degrees Fahrenheit.

Analyses of Fertilizers and Basis of Calculating Costs of Applications

Plants can use phosphorus in fertilizers only when it is present in an available form. Table 1 presents the average available phosphate present and the cost per ton of the various phosphate fertilizers used in this study. These analyses were taken from reports of the agencies making the products and from analyses run by the Agricultural Chemistry Department, University of Idaho. The average cost of western treble superphosphate in Idaho during 1938 was used as a basis of calculating the cost of the TVA and Bureau of Chemistry and Soils products as commercial prices were unavailable. The cost of rock phosphate was based on an average of prices quoted at various southern Idaho points in 1938. The price varied from $10 to $25 per ton.

The rates of application were not the same in all tests using the same test crop. Therefore, the rates of application given in Tables 2 to 4 are the average of all the rates used in the tests.

Table 1. Average available phosphate content and cost per ton of fertilizers used in field tests.

Fertilizer	Total Phosphate as P_2O_5 Per Cent	Available Phosphate as P_2O_5 Per Cent	Price Per Ton Dollars
Rock phosphate	30-40	2.0-5.5	15.00
Western treble superphosphate	45.0	43.0	50.00
TVA triple superphosphate	48.1	46.0	53.35
TVA meta phosphate	63.9	60.0	69.60
TVA fused phosphate	29.0	26.0	30.15
Bureau of Chemistry and Soils calcined phosphate	37.4	33.0	38.30

Results Obtained from Tests Conducted During 1937 and 1938

Yields of crops may vary widely from year to year as a result of seasonal and climatic variations such as temperature and precipitation, insect and disease injury, time and amount of irrigation, soil variations within the same field or test area, and numerous other factors already mentioned. Thus it is evident that unless special care is used in selecting the test area and caring for the crop, variations in yield may be obtained which are not the result of fertilizer applications. Thus erroneous con-

clusions may be drawn unless results are obtained from numerous or from carefully controlled tests over a period of years.

The results obtained are presented under each agency supervising the gathering of the data.

University Extension Division

The test crops used by the Extension Division included alfalfa, red clover, sugar beets, potatoes, oats, peas and beans. The alfalfa, beets, and potato tests were distributed from Payette County in southwestern Idaho to Fremont County in southeastern Idaho. All tests were conducted on irrigated farms. The data obtained in the various tests are presented in Table 2.

The alfalfa tests which include rock phosphate were started on eight farms in 1937 and on two farms in 1938. The reason for dividing the alfalfa tests into two divisions was to obtain a direct comparison in all tests where rock phosphate was included. The phosphate treatments included both finely ground and regular rock phosphate, western treble super, TVA meta, TVA fused, and Bureau calcined.

The rates of application per acre were determined on the basis of their available phosphate content. The amount of available phosphate present in western treble superphosphate application was used as the standard application. The other fertilizers were applied at a rate to supply an equivalent amount of available phosphate.

The application of western treble and TVA triple produced increased yields at relatively low costs per ton as compared with the costs where TVA meta and TVA fused phosphates were applied in the alfalfa tests which did not include rock phosphate.

The fertilizer cost per ton of increased yield of red clover hay was about the same for western treble and TVA triple. Very little difference in fertilizer cost per ton of increased yield of sugar beets was obtained from western treble and TVA triple. Similarly the fertilizer cost per hundredweight of increased yield of potatoes was the same for western treble and TVA triple. Since TVA meta and TVA fused were applied in only a limited number of tests with sugar beets and TVA meta with potatoes, the results obtained are not directly comparable with those obtained from the other two phosphate fertilizers mentioned previously.

The increased yields of beets receiving western treble and TVA triple superphosphate applications varied from none to 10 tons per acre and the increased yields of potatoes varied from none to 205 sacks per acre in individual fields.

Since only one test was conducted using barley, oats, beans, and peas as test crops, the results obtained apply only under similar conditions.

Idaho Phosphate Commission

The majority of the tests supervised by the phosphate commission (in 1938 only) were located in southwestern Idaho while a few were located in south central Idaho. Results included in this report are only

Table 2. Effect of various phosphate fertilizers on yields of different crops and fertilizer cost to secure unit increase in yield. Extension Division, 1937-38.

Crop and Treatment	Application rate per acre	Number of tests	Average calculated yield per acre	Increase	Cost of fertilizer application per acre	Cost of fertilizer to secure unit increase in yield
	lb.		ton 3 cuttings[1]	ton	dollar	dollar
ALFALFA						
Untreated		10	4.14			
Rock phosphate, fine	432	10	4.44	0.30	3.24	10.80
Rock phosphate, regular	508	10	4.23	0.09	3.81	42.33
Western treble	125	10	5.58	1.44	3.13	2.17
TVA triple						
TVA meta	87	10	4.83	0.69	3.03	4.39
TVA fused	210	10	4.35	0.21	3.17	15.10
Bureau calcined	171	10	4.74	0.60	3.27	5.45
ALFALFA[2]						
Untreated		18	4.17			
Western treble	165	18	4.95	0.78	4.13	5.29
TVA triple	165	18	5.01	0.84	4.41	5.25
TVA meta	160	3	4.51	0.34	5.57	16.38
TVA fused	160	2	4.23	0.06	2.42	40.33
RED CLOVER HAY			2 cuttings			
Untreated		6	6.00			
Western treble	125	6	6.81	0.81	3.13	3.86
TVA triple	125	6	7.00	1.00	3.34	3.34

(1) The total yields were determined by taking the average yield obtained per cutting and multiplying by 3 to make it comparable with the usual farm practice of harvesting three cuttings. This was necessary because, while three cuttings were obtained by the cooperators, they reported on less than three in some cases.

(2) Alfalfa tests started in 1938 in which only western treble and TVA products were compared.

TABLE 2 (Cont.)

Crop and Treatment	Application rate per acre	Number of tests	Average calculated yield per acre	Increase	Cost of fertilizer application per acre	Cost of fertilizer to secure unit increase in yield
	lb.		ton	ton	dollar	dollar
SUGAR BEETS						
Untreated		21	16.8			
Western treble	100	21	18.6	1.8	2.50	1.39
TVA triple	100	21	18.5	1.7	2.67	1.57
TVA meta	125	5	18.4	1.6	4.35	2.72
TVA fused	125	4	18.3	1.5	1.89	1.26
			cwt.	cwt.		
POTATOES						
Untreated		12	183			
Western treble	100	12	234	51	2.50	0.05
TVA triple	100	12	241	58	2.67	0.05
TVA meta	125	2	211	28	4.35	0.16
			bu.	bu.		
RED CLOVER SEED						
Untreated		10	2.86			
Western treble	190	8	3.55	0.69	4.75	6.88
TVA triple	180	9	3.01	0.15	4.81	32.07
OATS						
Untreated		1	18.3			
Western treble	125	1	26.5	8.2	3.13	0.38
TVA triple	125	1	25.5	7.2	3.34	0.46

TABLE 2 (Cont.)

Crop and Treatment	Application rate per acre	Number of tests	Average calculated yield per acre	Increase	Cost of fertilizer application per year	Cost of fertilizer to secure unit increase in yield
	lb.		bu.	bu.	dollar	dollar
PEAS						
Untreated		1	24.7			
Western treble	100	1	35.8	11.1	2.50	0.23
TVA triple	100	1	39.1	14.4	2.67	0.19
BEANS						
Untreated		1	10.8			
Western treble	125	1	12.3	1.5	3.13	2.09
TVA triple	125	1	11.8	1.0	3.34	3.34

those on which the yield could be calculated to the acre basis. This was necessary in order to calculate the costs of the increased yields obtained by the use of the various fertilizers.

The test crops were alfalfa, sugar beets, potatoes, onions, wheat, red clover seed, corn, barley, and oats. The phosphate treatments in most cases, included rock phosphate, western treble superphosphate, and TVA triple superphosphate. A summary of the results obtained are shown in Table 3.

Since TVA triple was applied to only two of the five alfalfa tests and only one cutting was obtained in each case, the results obtained from application of this product were not included in this report. The average cost per ton increase of alfalfa was more than twice as much from the rock phosphate treated plats as from western treble treated plats.

Sugar beet yield increases of 2.81 and 1.46 tons above the untreated plats, were obtained from western treble and TVA triple treated plats, at a fertilizer cost of $.89 and $1.83 per ton, respectively, while practically no increase in yield was obtained from the rock phosphate treated plats.

The cost per bushel of increased yield of wheat was over three times greater when rock phosphate was applied than when western treble and TVA triple were applied. The same general relationship was found with corn, the fertilizer cost of the increase being from nearly two to over three times as great. There were practically no differences in the cost of increased potato yields from the application of the rock phosphate and available phosphates. This was not in agreement with the data obtained in a series of tests conducted in southeastern Idaho in 1931-32 (*10*) in which very little response was obtained from the application of rock phosphate.

The number of tests in which oats, barley, onions, and red clover seed were used as tests crops were insufficient on which to base definite conclusions. No increase in yield was obtained from any of the phosphate fertilizers applied to oats as the crop was severely damaged by hail. An increased yield of onions was obtained by the application of available phosphate but no benefit was obtained from the rock phosphate application. The application of rock phosphate increased the yield of barley, in the one test reporting yields, at a lower cost than did TVA triple; however, this increased yield was not profitable as the fertilizer cost per bushel increase was approximately the selling price of the crop.

The results obtained in the two red clover seed tests conducted in southeastern Idaho do not present a true picture of the value of phosphate fertilization in forage legume seed production. Available phosphate fertilization has a tendency to delay maturity, as a result the variously fertilized plats of the test did not ripen simultaneously although for obtaining the reported yields the plats were all harvested at the same time. Thus a large percentage of immature seeds were harvested and lost in the hulling process. The Aberdeen Branch Experiment Station (*12*) and numerous farmers in southern Idaho have more than doubled the seed yield of red clover by the application of readily available phosphate fertilizers.

Table 3. Effect of various phosphate fertilizers on yields of different crops and fertilizer cost to secure unit increase in yield. Idaho Phosphate Commission (1) 1938.

Crop and Treatment	Application rate per acre	Number of tests	Average calculated yield per acre	Increase	Cost of fertilizer application per acre	Cost of fertilizer to secure unit increase in yield
ALFALFA HAY[2]	lb.		ton	ton	dollar	dollar
Untreated		5	4.23			
Rock Phosphate	500	5	4.56	0.33	$3.75	$11.36
Western treble	100	5	4.74	0.51	2.50	4.90
SUGAR BEETS						
Untreated		7	15.82			
Rock phosphate	200	6	15.89	0.07	1.50	21.43
Western treble	100	7	18.63	2.81	2.50	0.89
TVA triple	100	7	17.28	1.46	2.67	1.83
POTATOES			cwt.	cwt.		
Untreated		6	185			
Rock phosphate	200	6	200	15	1.50	0.10
Western treble	100	6	209	24	2.50	0.10
TVA triple	100	6	210	25	2.67	0.11
ONIONS						
Untreated		1	498			
Rock phosphate	100	1	466	none	0.75	value entirely lost
Western treble	50	1	514	16	1.25	0.08
WHEAT			bu.	bu.		
Untreated		10	46.2			
Rock phosphate	500	10	48.2	2.0	3.75	1.88
Western treble	100	9	50.5	4.3	2.50	0.58
TVA triple	100	8	51.3	5.1	2.67	0.52

(1) Summarized from "Report on Phosphate Fertilizers" Idaho Phosphate Commission, 1938.
(2) The total yields were determined by taking the average yield obtained per cutting and multiplying by 3 to make it comparable with the usual farm practice of harvesting three cuttings. This was necessary because, while 3 cuttings were obtained by the cooperators, they reported on less than 3 in some cases.

TABLE 3. (Cont.)

Crop and Treatment	Application rate per acre	Number of tests	Average calculated yield per acre	Increase	Cost of fertilizer application per acre	Cost of fertilizer to secure unit increase in yield
	lb.		bu.	bu.	dollar	dollar
RED CLOVER SEED						
Untreated		2	3.23			
Rock phosphate	500	1	4.75	1.52	$3.75	$2.47
Western treble	100	2	3.83	.60	2.50	4.17
TVA triple	100	2	4.95	1.72	2.67	1.55
CORN						
Untreated		5	67.2			
Rock phosphate	200	5	70.5	3.3	1.50	0.45
Western treble	100	5	77.9	10.7	2.50	0.23
TVA triple	100	4	88.0	20.8	2.67	0.13
BARLEY						
Untreated		1	66.0			
Rock phosphate	500	1	75.0	9.0	3.75	0.42
TVA triple	100	1	70.0	4.0	2.67	0.67
OATS[1]						
Untreated		1	87.0			
Rock phosphate	500	1	73.0	none	3.75	
Western treble	100	1	70.0	none	2.50	
TVA triple	100	1	73.0	none	2.67	

(1) "This plat was affected by hail storm; one side of the plat was damaged more than the other. The results are not a true test." Idaho Phosphate Commission Report.

Table 4. Effect of various phosphate fertilizers on yields of alfalfa hay and fertilizer cost to secure 1 ton increase in yield. Aberdeen Branch Experiment Station. 1937-38

Treatment	Average[1] Application rate per acre	Number of Tests	Average yield per acre[2]	Increase	Cost of fertilizer application	Cost of fertilizer to secure 1 ton increase in yield
	lb.		ton	ton	dollar	dollar
Untreated		2	3.31			
Rock phosphate	385	2	3.51	.20	$2.89	$14.45
Rock phosphate	1900	2	3.27	none	14.25	value entirely lost
Western treble	125	2	5.34	2.03	3.13	1.54
TVA triple	125	2	5.57	2.26	3.34	1.48
TVA meta	90	2	4.22	0.91	3.13	3.44
TVA fused	208	2	3.33	0.02	3.13	156.50
Bureau calcined	168	2	4.10	0.79	3.21	4.06

(1) Slightly different rates were used in the two tests. The rates given the table are the average of the different rates.
(2) Based on three cuttings per year.

Experiment Station

The Experiment Station investigations comparing the value of the various phosphate fertilizers on alfalfa for southern Idaho conditions were conducted at the Aberdeen Branch Experiment Station.

Table 4 shows the results obtained. These tests, although few in number, were conducted under carefully controlled experimental conditions so the results obtained should be indicative of what might be expected from the various phosphate fertilizers under similar southern Idaho conditions.

The greatest increases in yield were obtained from TVA triple and western treble. No benefit was obtained from the heavy application of rock phosphate and only slight increases from the light application of rock phosphate and TVA fused. The responses from TVA meta and Bureau calcined were intermediate.

The fertilizer cost to secure 1 ton of alfalfa hay above the untreated plats by western treble and TVA triple was $1.54 and $1.48 respectively, while for TVA meta and Bureau calcined, it was $3.44 and $4.06 respectively. For rock phosphate, the fertilizer cost for the increased hay produced by the light application was $14.45, while for the heavy application the $14.25 invested in fertilizer was entirely lost, for the average yield was slightly lower than obtained from the untreated plats.

Discussion

Data gathered on the relative value of the various phosphate fertilizers by the Experiment Station and Extension Division of the University of Idaho during 1937 and 1938, and the Idaho Phosphate Commission during 1938, have been presented in tables 2, 3 and 4, respectively.

Where a supervising agency obtained results on the same crop from only one or two cooperative farmer tests for a single season, the results obtained cannot be considered as representative as those obtained in a larger number of tests over a period of years.

Alfalfa was used as the test crop in 35 tests on farms located in the Snake, lower Boise, and lower Payette river valleys, from Payette County in the southwest to Jefferson County in the southeast. Western treble and TVA triple were equally satisfactory as sources of readily available phosphate for alfalfa. The results obtained from the application of the other phosphate fertilizers indicate that they cannot be used as profitably on alfalfa in southern Idaho as the more readily available forms.

In the tests reported in this publication, the increased yields of beets were produced at a slightly lower cost by the use of western treble than by the use of TVA triple. The greater difference occurred in the tests supervised by the Idaho Phosphate Commission. Rock phosphate was compared with western treble and TVA triple by only one supervising agency and the cost per ton increase was found to be very high.

Profitable returns were obtained from the use of phosphates on potatoes in the tests reported in this publication. In the 6 tests supervised by the Idaho Phosphate Commission, the fertilizer cost per hundredweight o.

increased yield was .10 for western treble and rock phosphate and .11 for TVA triple. The benefit obtained from rock phosphate is not in agreement with the results obtained in a series of fertilizer tests conducted in southeastern Idaho in 1931-32. (*10*) Experiments at the Aberdeen Branch Station (*12*) have indicated ". . . when potatoes are grown in a balanced rotation in which the legumes have sufficient available phosphorus for proper development that the use of a phosphate fertilizer is not profitable."

It has not been possible to consider fully the residual value of phosphate fertilizer applications in this presentation. Data dealing with residual effects were obtained from only three alfalfa tests. The yield increases obtained the 2nd year after application were only slightly less than those obtained the year that the phosphate fertilizer was applied. In other tests started previous to 1937, increased yields of alfalfa have been obtained 3 and 4 years after application of readily available phosphate fertilizer. (*5*) (*6*) (*7*) (*8*).

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